(19) Europäisches Patentamt
European Patent Office
Office europ´en des brevets

(11) Publication number: 0 276 817
A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 88101116.7

(51) Int. Cl.[4]: H01Q 25/00 , H01Q 3/26

(22) Date of filing: 26.01.88

(30) Priority: 27.01.87 JP 10010/87 U
06.02.87 JP 25865/87
06.02.87 JP 25866/87

(43) Date of publication of application:
03.08.88 Bulletin 88/31

(84) Designated Contracting States:
DE FR GB

(71) Applicant: MITSUBISHI DENKI KABUSHIKI KAISHA
2-3, Marunouchi 2-chome Chiyoda-ku
Tokyo 100(JP)

(72) Inventor: Saito, Jun c/o Kamakurasaisakusho
Mitsubishi Denki K.K. 325, Kamimachiya
Kamakura-shi Kanagawa-ken(JP)
Inventor: Haruyama, Tetsuo c/o
Kamakurasaisakusho
Mitsubishi Denki K.K. 325, Kamimachiya
Kamakura-shi Kanagawa-ken(JP)
Inventor: Orime, Nobutake c/o
Kamakurasaisakusho
Mitsubishi Denki K.K. 325, Kamimachiya
Kamakura-shi Kanagawa-ken(JP)
Inventor: Katagi, Takashi c/o
Kamakurasaisakusho
Mitsubishi Denki K.K. 325, Kamimachiya
Kamakura-shi Kanagawa-ken(JP)

(74) Representative: Pfenning, Meinig & Partner
Mozartstrasse 17
D-8000 München 2(DE)

(54) Conformal array antenna.

(57) A conformal array antenna system is disclosed comprising a structural base body having a shape suitable for a surface of an airplane or a ship, and a plurality of antenna units disposed on the structural base body. Signals received by these antenna units are converted into digital signals and fed to a digital beam forming circuit which synthesizes such digital signals to form a multiplicity of beams. The antenna units and the digital beam forming circuits may be connected by electrical transmission lines or optical fibers.

EP 0 276 817 A2

CONFORMAL ARRAY ANTENNA

The present invention relates to a conformal array antenna for use with a radar system.

Fig. 1 illustrates a block diagram of a prior art antenna system. In the figures the reference numeral 1 designates a conformal array antenna including a structural base body 2 assuming a semi-spherical configuration and a number n of antenna units 3_1 to 3_n arrayed on the structural base body 2. A number n of signal lines 4_1 to 4_n interconnect the antenna units 3_1 to 3_n and a microwave beam forming circuit 5. Each of the antenna units 3_1 to 3_n which constitute the conformal array antenna 1 is an independent unitary antenna device.

Next, the operation of the prior art antenna system will be described. A microwave power is received by the antenna units 3_1 to 3_n arrayed on the semi-spherical structural base body 2 of the conformal array antenna 1, and is transmitted via the signal lines 4_1 to 4_n to the microwave beam forming circuit 5 where the microwave signals are synthesized to form a multiplicity of beams by making use of microwave phase shifters, microwave variable attenuators, microwave switches and microwave couplers.

In the thus constructed conventional antenna system, the antenna beams can be arbitrarily formed over the semi-sphere. In the case of forming a multiplicity of beams by employing microwave devices such as a phase shifter, an attenuator, a switch, a coupler and a distributor, however, the configuration loss becomes larger and only a limited number of beams can be formed concurrently. Supposing that a beam is oriented in a desired direction when used as a part of the radar system, the shadowed units among the antenna units 3_1 to 3_n when viewing the conformal array antenna 1 from the desired direction cannot be effectively utilized. Especially when a scanning angle approximates to 90° from the zenith, almost half of the elements are not available for use.

A general object of the present invention is to eliminate the problems described above.

It is an object of the present invention to provide an antenna system capable of simultaneously synthesizing a plurality of beams and constantly utilizing all the antenna units in an effective manner.

In order to accomplish the above object, an antenna system according to the present invention comprises a plurality of antenna units each of which is adapted to convert outputs from an element antenna into a digital signal, and a digital beam forming circuit. The digital beam forming circuit effects a parallel process for synthesizing digital signals including phase and amplitude information supplied from the respective antenna units. It is, therefore, possible to concurrently synthesize the digital signals to form a multiplicity of beams, which permits effective utilization of all the antenna units. Additionally, the problems that are caused by cross polarization can be eliminated. Moreover, a considerable improvement in performance is provided with respect to multi-target processing, expansion of the antenna beam scanning range, interconnection with other signal processing systems based on digital processing, and miniaturization of the antenna system.

It is another object of the invention to provide an antenna system capable of simultaneously synthesizing digital signals to form a multiplicity of beams, utilizing all the antenna units effectively and reducing the electromagnetic interference between signal lines interconnecting the antenna units and a digital beam forming circuit.

In order to achieve this object, an antenna system according to the present invention comprises a plurality of antenna units each having photo-modulator means. The output from the photo-modulator means is sent by optical fibers to photo-demodulator means which convert the light signals to the corresponding electrical signals. These electrical signals are in a digital form and are supplied to a digital beam forming circuit. The digital beam forming circuit is capable of processing the digital signals including phase-amplitude information by effecting a parallel process for synthesizing such digital signals. It is, therefore, possible to concurrently form a multiplicity of beams, which permits effective utilization of all the antenna units. Because the optical fibers are employed for transmission of the signals, the problem caused by the electromagnetic interference is greatly reduced.

It is still another object of the present invention to provide an antenna system capable of simultaneously synthesizing a multiplicity of beams, utilizing all the antenna units in an effective manner, and solving the problems that are caused by electromagnetic interference and cross polarization attributed to the difference in polarization between the antenna units.

In order to achieve third object, an antenna system of the present invention comprises a plurality of antenna units each including a transmitting section, a receiving section and a TR switch. The transmitting sections include a phase controller and are connected to a microwave power distributor, while the receiving sections include a low-noise amplifier and th rec ived signals are converted to digital signals and f d to a digital beam forming circuit. The digital beam forming circuit serves to

process the digital signals including phase-amplitude information for arbitrarily synthesizing these signals to form multiple beams simultaneously and to enable all the antenna units to be utilized effectively. Moreover, because the transmitting section and the receiving section are incorporated to use the same element antenna, the problems caused by cross polarization are eliminated. If the signals are transmitted through optical fibers, a remarkable reduction in the electromagnetic interference can be expected and the signal transmission lines can be miniaturized.

Other features and advantages of the invention will be apparent from the following description taken in connection with the accompanying drawings.

Fig. 1 is a schematic illustration of a conventional conformal array antenna system;

Fig. 2 is a block diagram of a first embodiment of a conformal array antenna system according to the present invention;

Fig. 3 is a block diagram of an antenna unit of the conformal array antenna system shown in Fig. 2;

Fig. 4 shows in detail the structure of the conformal array antenna system shown in Fig. 2;

Fig. 5 is a schematic diagram of the DPSD shown in Fig. 4;

Fig. 6 is a block diagram of a second embodiment of a conformal array antenna system according to the present invention;

Fig. 7 is a block diagram of an antenna unit of the conformal array antenna system shown in Fig. 6;

Fig. 8 is a modified form of the second embodiment;

Fig. 9 is a block diagram of a third embodiment of a conformal array antenna system according to the present invention;

Fig. 10 shows the structure of the antenna unit shown in Fig. 9;

Fig. 11 is a block diagram of a fourth embodiment of a conformal array antenna system according to the present invention; and;

Fig. 12 is a modified form of the fourth embodiment.

Fig 2 shows the first embodiment of the present invention which is embodied as a receiving antenna system or a passive detection antenna system for use with a separate transmitting antenna system.

In Fig. 2, a conformal array antenna 10 includes a structural base body 11 which assumes a semi-spherical configuration and a number n of antenna units 12_1 to 12_n arrayed on the structural base body 11. A number n of signal lines 13_1 to 13_n interconnect the antenna units 12_1 to 12_n and a digital beam forming circuit 14. The antenna units 12_1 to 12_n hav th same structur . Fig. 3 shows a schematic diagram of the antenna unit 12_1 as an example. The antenna unit 12_1 comprises an element antenna 12_{11}, a low-noise amplifier 12_{12} and an A/D converter 12_{13}.

Next the operation of the antenna system will be explained with reference to Figs. 2 and 3. Microwave signals are received by the element antennas 12_{11} to 12_{n1} of the antenna units 12_1 to 12_n which are fixed to the structural base body 11 of the conformal array antenna 10. The received microwave signals are then amplified by the low-noise amplifiers 12_{12} to 12_{n2}, the outputs of which are, directly or after being converted into the IF signals, supplied to A/D converters 12_{13} to 12_{n3} which convert the supplied microwave signals to digital signals including phase and amplitude information. The digital signals are transmitted via the signal lines 13_1 to 13_n to the digital beams forming circuit 14, in which the signals are synthesized as the digital signals to form multiple-beams by employing known techniques such as discrete Fourier transformation, fast Fourier transformation and Winograd Fourier transformation. Hence, it is feasible to digitally effect a parallel process of a plurality of signals transmitted from the antenna units 12_1 to 12_n in accordance with arbitrary beam configurations. Pieces of information sent from all the antenna units 12_1 to 12_n can be processed at any time in an effective manner, thereby enabling the information arriving from all directions in the semi-sphere to be obtained.

Generally speaking, the amplitudes and phases at the antenna aperture of each of the antenna units 12_1 to 12_n are different from each other in correspondence with the position of the antenna units and the direction of the incoming waves. Accordingly, the signal e_i received by the element antenna 12_{i1} of the antenna unit 12_i is expressed as follows:

$$e_i = g_i e^{j\phi_i} \qquad i = 1, 2, ..., n$$

wherein g_i is an element pattern of the element antenna 12_{i1} and is a complex amount that depends on the position of the element antenna, and ϕ_i represents an electrical length which is equivalent to the difference between the mutual distances of the respective element antenna, the received signal e_i thus being a complex number.

Referring now to Fig. 4, there is shown in schematic form the structure of the conformal array antenna system as shown in Fig. 2. As shown in Fig. 4, the digital beam forming circuit 14 includes a number n of serial-to-parallel converters 14_{11} to 14_{n1} connected respectively to the signal lines 13_1 to 13_n, a number n of digital phas sensitive detectors 14_{12} to 14_{n2} connected to the corresponding serial-to-parallel converters, and a digital beam forming unit 15 for producing a plurality of output signals at output port P_1 to P_n. The signal lines 13_1

to 13_n carry m-bit digital signals from the analogue-to-digital converters 12_{i_3} to $12_{n_3}$to the serial-to-parallel converters 14_{i_1} to 14_{n_1}.

An explanation will be made by giving instances of the procedure of processing the microwave signal impinging on the antenna unit 12_i.

The microwave reflected by a target and received by the element antenna 12_{i_1} is an analogue signal. The analogue signal thus received is in turn amplified by the low-noise amplifier 12_{i_2} with the relative relationship between the amplitude and the phase maintained. The amplified signal is fed to the analogue-to-digital converter 12_{i_3} in which the signal is sampled and quantized to form an m-bit digital signal. The m-bit signal is transmitted through the signal line 13_i to the serial-to-parallel converter 14_{i_1} in the digital beam forming circuit 14.

In the digital beam forming circuit, the m-bit serial signal from the line 13_i is converted to an m-bit parallel signal by the serial-to-parallel converter 14_{i_1}. The parallel signal is sent every sampling time to the digital phase sensitive detector (DPSD) 14_{i_2} which converts the input signal to an I-signal and a Q-signal having the following relation:

$e_i = I_i + jQ_i$

Fig. 5 shows an example of the DPSD. The input signal to the DPSD 14_{i_2} is divided into two portions which are multiplied by the sine and cosine waves, respectively, to output two separate signals I_i and Q_i which are to be supplied to the digital beam forming unit 15. Similar to this, the signals received by the remaining antenna units are processed and sent to the digital beam forming unit 15. The digital beam forming unit is well-known as a discrete Fourier transform (DFT) beamformer, a fast Fourier transform (FFT) beamformer or a Winograd transform beamformer. Accordingly, the output signals corresponding respectively with n directions θ_1 to θ_n are obtained from the output port P_1 to P_n. For example, the output signal E_i at the port $P_i$is expressed as follows:

$E_i = I_i + jQ_i$

$|E_i| = (I_i^2 + Q_i^2)^{1/2}$

$<E_i = \tan^{-1}(Q_i/I_i)$

Turning now to Fig. 6, the second embodiment of the present invention is shown. In Fig. 6, identical components and elements are designated by the same numerals as those used in Figs. 2 through 5. A number n of antenna units 20_1 to 20_n arrayed on the structural base body 11 are connected through optical fibers 21_1 to 21_n to a number n of photo-demodulators 22_1 to 22_n which are, for example, photoelectric converters. The outputs from the photo-demodulators are fed to the digital beam forming circuit 14 for synthesis. The antenna units 20_1 to 20_n are of the same structure. Fig. 7 shows a block diagram of the antenna unit 20_1 as an example. As shown in the figure, the antenna unit 20_1 comprises an element antenna 20_{1_1}, a low-noise amplifier 20_{1_2} connected to the element antenna 20_{1_1}, an analogue-to-digital converter 20_{1_3} connected to the low-noise amplifier 20_{1_2} and a photo-modulator 20_{1_4} connected to the analogue-to-digital converter 20_{1_3}. The photo-modulator may be a conventional electro-photo converter.

Next, the operation of the antenna system will be described. Microwave signals are received by the element antennas 20_{1_1} to 20_{n_1} of the antenna units 20_1 to 20_n and then amplified by the low-noise amplifiers 20_{1_2} to 20_{n_2}. The thus amplified microwave signals are, directly or after being converted into the IF signals, supplied to the A/D converters 20_{1_3} to 20_{n_3} to be converted to digital signals including the phase and amplitude information. The digital signals are then converted into photo-signals by the photo-modulators 20_{1_4} to 20_{n_4} and transmitted via the optical fibers 21_1 to 21_n to the photo-demodulators 22_1 to 22_n. The digital electric signals thus demodulated by the photo-demodulators 22_1 to 22_n are supplied to the digital beam forming circuit 14 which synthesizes the digital signals by employing known techniques such as discrete Fourier transformation, fast Fourier transformation and Winograd Fourier transformation. Also in the second embodiment, it is feasible to digitally effect a parallel process of a plurality of the signals received by the antenna units 20_1 to 20_naccording to arbitrary antenna beam configurations. Pieces of information received by the antenna units 21_1 to 21_n can be processed in an effective manner, thereby obtaining the information from all directions in the semi-sphere. Because the optical fibers are used as transmission lines, no problem of electromagnetic interference can happen. Also, the signal lines can be miniaturized.

The A/D converters 20_{1_3} to 20_{n_3} are inserted between the low-noise amplifiers and the photo-modulators in Fig. 7, but each A/D converter may, as illustrated in Fig. 8, be disposed between the photo-demodulator and the digital beam forming circuit. In this case, the photo-modulators 20_{1_4} to 20_{n_4} convert the microwave signals, directly or after being converted into the IF signals, into the photo-signals. The thus converted photo-signals are transmitted via the optical fibers 21_1 to 21_n to the photo-demodulators 22_1 to 22_n to be demodulated to the electrical signals. The demodulated electrical signals are converted, directly or after being converted into the IF signals, into the digital signals by means of the A/D converters 20_{1_3} to 20_{n_3}.

The two embodiments described above relate to receiving antenna systems. On the other hand, the third and fourth embodiments shown in Figs. 9 through 12 are systems capable of transmitting and receiving microwave signals. In these figures, identical elements and components are designated by

the same reference numerals as those used in Figs. 1 through 8.

Referring now to Fig. 9, a number n of antenna units 30_1 to 30_n arranged on the semi-spherical body 11 of the conformal array antenna 10 are connected through a number n of sending lines 31_1 to 31_n to a microwave power distributor 32 that is receiving microwave power from a transmitting signal generator 33. The antenna units 30_1 to 30_n are also connected through a number n of receiving lines 34_1 to $34_n$to the digital beam forming circuit 14 which synthesizes input digital signals to form a multiplicity of beams.

Fig. 10 is a more detailed illustration of the conformal array antenna system shown in Fig. 9. As seen in Fig. 10, all the antenna units 30_1 to 30_n have the same circuit structures. Element antennas 30_{11} to 30_{n1} are connected through TR switches 30_{12} to 30_{n2} to transmitting sections 30_{13} to 30_{n3} and to receiving sections 30_{14} to 30_{n4}. These TR switches 30_{12} to 30_{n2} may be conventional circulators or diode switches. The transmitting sections 30_{13} to 30_{n3} include high power amplifiers 30_{15} to 30_{n5} and phase controllers 30_{16} to 30_{n6}, while the receiving sections 30_{14} to 30_{n4} include low-noise amplifiers 30_{17} to 30_{n7} and analogue-to-digital converters 30_{18} to 30_{n8}.

Next, the operation of the antenna system of Fig. 10 will be explained. A microwave signal received from the signal generator 33 and input to the microwave power distributor 32 is distributed to a number n of outputs each having a desired amplitude and phase. These output signals are transmitted via the sending lines 31_1 to 31_n to the transmitting sections 31_{13} to 31_{n3} of the antenna units 30_1 to 30_n. In the transmitting sections, the microwave signals undergo phase changes in the phase controllers 30_{16} to 30_{n6} so as to form desired antenna beams. Then the phase-controlled microwave signals are amplified by the high power amplifiers 30_{15} to 30_{n5}, pass through the TR switches 30_{12} to 30_n, and are then emitted from the element antennas 30_{11} to 30_{n1} into space. The microwave signals which have been emitted into space are reflected by a target and received by the element antennas 30_{11} to 30_{n1}. Subsequently, the received microwave signals are transmitted via the TR switches 30_{12} to 30_{n2} to the receiving sections 30_{14} to $30_{n4}$of the antenna units. The microwave signals input to the receiving sections 30_{14} to 30_{n4} are amplified by the low-noise amplifiers 30_{17} to 30_{n7}. The thus amplified microwave signals are fed, directly or after being converted into the IF signals, to the analogue-to-digital converters 30_{18} to 30_{n8} which in turn convert the input analogue signals into digital signals including phase and amplitude information. These digital signals are transmitted via the receiving lines 34_1 to 34_n to the digital b am forming circuit 14 in which the signals are synthesized to form multiple beams by employing known techniques such as discrete Fourier transformation, fast Fourier transformation and Winograd Fourier transformation. Hence, it is possible to digitally effect a parallel process of the signals sent from the antenna units 30_1 to 30_n in accordance with arbitrary beam configurations. Furthermore, the information from all the antenna units can be processed unfailingly in an effective manner, thereby constantly obtaining information from all directions in the semi-sphere.

When antenna units 30_1 to 30_n, which are adapted for a linearly polarized wave are employed, the polarization of the transmitted signal is the same as that of the signals received after being reflected by the target, if consideration is given to the individual element antennas 30_{11} to 30_{n1}. The signals reflected by and coming from the target are converted into digital signals including phase-amplitude information, and the digital signals are synthesized by the digital beam forming circuit 14, so the problem of cross polarization caused by the difference in polarization between the antenna units is solved.

The same operation as the third embodiment may be expected even when light signals are utilized for transmission of signals between the antenna units 31_1 to 31_n and the microwave power distributing circuit 32 and the digital beam forming circuit 14. Fig. 11 shows the fourth embodiment of the present invention which uses light signals for transmission of signals. In comparison with the third embodiment, the antenna units 40_1 to 40_n of the fourth embodiment include photo-modulators 40_{12} to 40_{n2} and photo-demodulators 40_{11} to 40_{n1}. The outputs from the microwave distributing circuit 32 are converted into light signals by the photo-modulators 41_1 to 41_n and are then transmitted via optical fibers 42_1 to 42_n to photo-demodulators 40_{11} to 40_{n1} added to the transmitting section 40_{13} to 40_{n3} of the antenna units. In the photo-demodulators, the light signals are converted into microwave signals to be transmitted. In reception, the digital signals are converted into light signals by means of the photo-modulators 40_{12} to 40_{n2} added to the receiving section 40_{14} to 40_{n4} of the antenna units. The thus converted light signals are transmitted via optical fibers 43_1 to 43_n to photo-demodulators 44_1 to 44_n to provide electrical signals to the digital beam forming circuit 14. In the fourth embodiment shown in Fig. 11, the light signals are employed for the transmission of signals between the devices, and hence the problem caused by electromagnetic interference between the signal lines is obviated, and the signal lines are of diminished size by virtue of the provision of the optical fibers.

Fig. 12 is a modification of the fourth embodi-

ment shown in Fig. 11. In this case, the analogue-to-digital converters 30_{1s} to 30_{ns} of the receiving sections are positioned between the photo-demodulators 44_1 to 44_n and the digital beam forming circuit 14. It can be expected that operation and effects similar to those achieved in the fourth embodiment will be exhibited.

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention. For example, the shape of the conformal array antenna system according to the present invention is need not be limited to the semi-sphere, but may be made to be fitted to the shape of certain structures such as ships, airplanes, missiles, vehicles, satellites and ground radar sites, or may be a portion of a cylinder, sphere or cone, or a portion or portions of a shape made as a combination of any two or three of a cylinder, a sphere and a cone. Further, the conformal array antenna system of the present invention can utilize not only linearly polarized waves but also circularly polarized waves.

Claims

1. A conformal array antenna system comprising:

a plurality of antenna units disposed on a structural base body having a predetermined shape, each antenna unit including means for converting a received analogue electrical signal into a digital electrical signal; and

digital beam forming means for synthesizing the digital electrical signals from said antenna units to form a multiplicity of beams.

2. An antenna system as defined in Claim 1 wherein each of said antenna units includes a lowe-noise amplifier for amplifying the analogue signal and an analogue-to-digital converter for converting the amplified analogue signal into the digital signal.

3. In a conformal array antenna system comprising a plurality of antenna units disposed on a structural base body having a predetermined shape, the improvement comprising:

a plurality of analogue-to-digital converters each included in said antenna unit for converting a received analogue electrical signal into a digital electrical signal, the digital electrical signals being transmitted to a digital beam forming circuit adapted to synthesize the digital electrical signals to form a multiplicity of beams.

4. A conformal array antenna system comprising:

a plurality of antenna units disposed on a structural base body having a predetermined shape, each antenna unit including means for converting a received electrical signal into a digital light signal;

optical fiber means for transmitting the digital light signals;

photo-demodulator means for converting the digital light signals from said optical fiber means into digital electrical signals; and

digital beam forming means adapted for synthesizing the digital electrical signal from said photo-demodulator means to form a multiplicity of beams.

5. An antenna system as defined in Claim 4 wherein said means for converting a received electrical signal comprises an analogue-to-digital converter for converting the received analogue signal into a digital signal, and a photo-modulator for converting the digital signal into a digital light signal.

6. A conformal array antenna system comprising:

a plurality of antenna units disposed on a structural base body having a predetermined shape, each antenna unit including means for converting a received analogue signal into an analogue light signal;

optical fiber means for transmitting the analogue light signals;

photo-demodulator means for converting the analogue light signals from said optical fiber means into analogue electrical signals;

A/D converter means for converting the analogue electrical signals from said photo-demodulator means into digital electrical signals; and

digital beam forming means adapted for synthesizing the digital electrical signals from said A/D converter means to form a multiplicity of beams.

7. A conformal array antenna system comprising:

a plurality of antenna units disposed on a structural base body having a predetermined shape, each antenna unit including an element antenna, a transmitting section, a receiving section and a TR switch for selectively connecting said element antenna and the transmitting section or the receiving section, each of said receiving sections including means for converting an analogue electrical signal from said element antenna into a digital electrical signal;

a transmitting signal generator means;

power distributing means for distributing an electrical signal from said transmitting signal generator means to said transmitting sections of said antenna units; and

digital b am forming means for synthesizing

the digital electrical signals from said receiving sections of said antenna units to form a multiplicity of beams.

8. An antenna system as defined in Claim 7 wherein said transmitting section includes a phase controller connected to said power distributing means and a high power amplifier connected to said TR switch.

9. A conformal array antenna system comprising:

a transmitting signal generating means;

means for distributing an electrical signal from said transmitting signal generating means;

photo-modulator means for converting the distributed electrical signals into light signals;

first optical fiber means for transmitting the light signals from said photo-modulator means;

a plurality of antenna units arranged to form a predetermined shape, each antenna unit including an element antenna, a transmitting section for converting the light signal from said first optical fiber means into an electrical signal, a receiving section for converting a received electrical signal to a digital light signal, and a TR switch for selectively connecting said element antenna and said transmitting section or said receiving section;

second optical fiber means for transmitting the digital light signals;

photo-demodulator means for converting the digital light signals from said second optical fiber means into digital electrical signals; and

digital beam forming means for synthesizing the digital electrical signals from said photo-demodulator means to form a multiplicity of beams.

10. An antenna system as defined in Claim 9 wherein said transmitting section includes a photo-demodulator for converting the light signal from said first optical fiber means into an electrical signal, a phase controller connected to said photo-demodulator and a high power amplifier connected to said phase controller, and wherein said receiving section includes a low-noise amplifier connected to said TR switch, an analogue-to-digital converter for converting a received analogue electrical signal into a digital electrical signal, and a photo-modulator for converting the digital electrical signal into a digital light signal.

11. A conformal array antenna system comprising:

a transmitting signal generating means;

power distributing means for distributing the signal from said signal generating means;

photo-modulator means for converting the distributed signals into a first light signal;

first optical fiber means for transmitting the first light signal;

a plurality of antenna units arranged to form a predetermined shape, each antenna unit including an element antenna, a transmitting section for converting the first light signal from said first optical fiber means into an electrical signal, a receiving section for converting a received electrical signal into a second light signal, and a TR switch for selectively connecting said element antenna and said transmitting section or said receiving section;

second optical fiber means for transmitting the second light signals from said receiving sections;

photo-demodulator means for converting the second light signals from said second optical fiber means into analogue electrical signals;

A/D converter means for converting the analogue electrical signals from said photo-demodulator means into digital electrical signals; and

digital beam forming means for synthesizing the digital electrical signals from said A/D converter means to form a multiplicity of beams.

12. An antenna system as defined in any one of the preceding claims wherein said digital beam forming means includes serial-to-parallel converters for converting the received serial digital signals into parallel signals, digital phase sensitive detectors for converting the parallel signals into I-signals and Q-signals, and a digital beam forming unit for synthesizing the I-and Q-signals to form a multiplicity of beams.

13. An antenna system as defined in Claim 12 wherein said digital beam forming unit is any one of a discrete Fourier transform beamformer, a fast Fourier transform beamformer or a Winograd transform beamformer.

Fig. 1

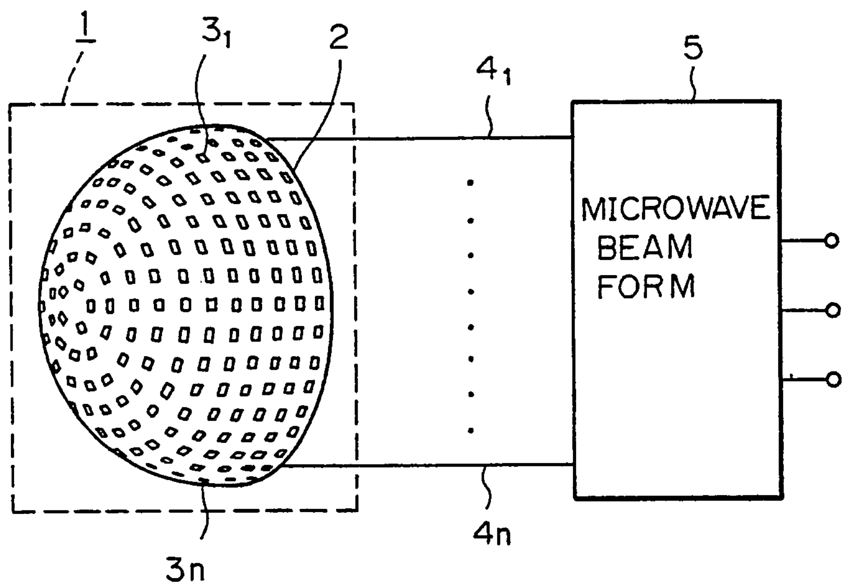


Fig. 2

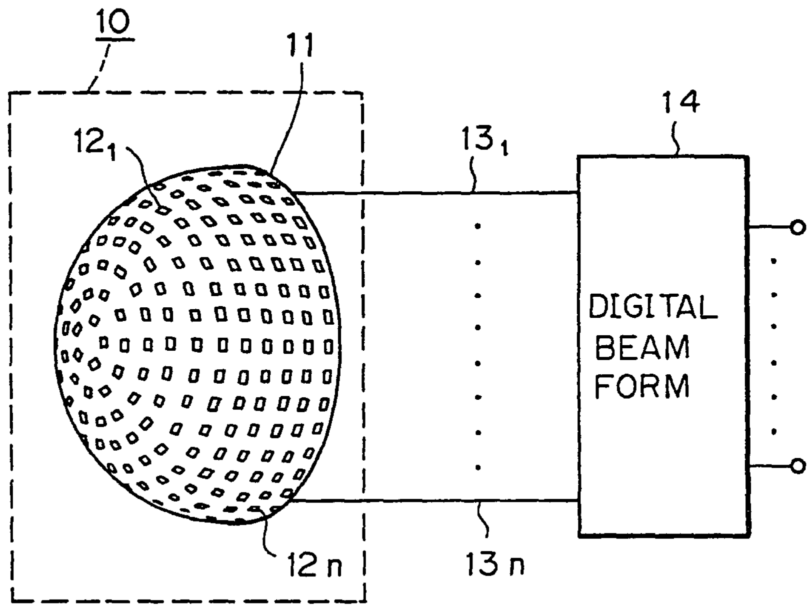

10
11
12_1
13_1
14
DIGITAL
BEAM
FORM
12 n
13 n

Fig. 3

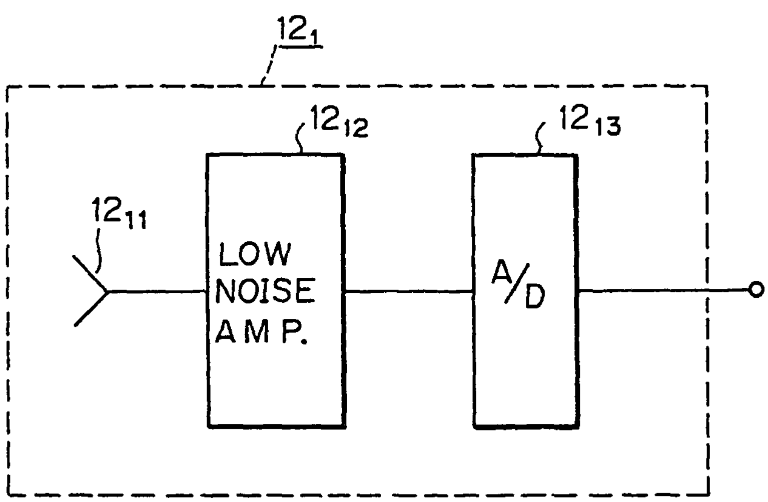

12_1
12_{12}
12_{13}
12_{11}
LOW
NOISE
AMP.
A/D

Fig. 4

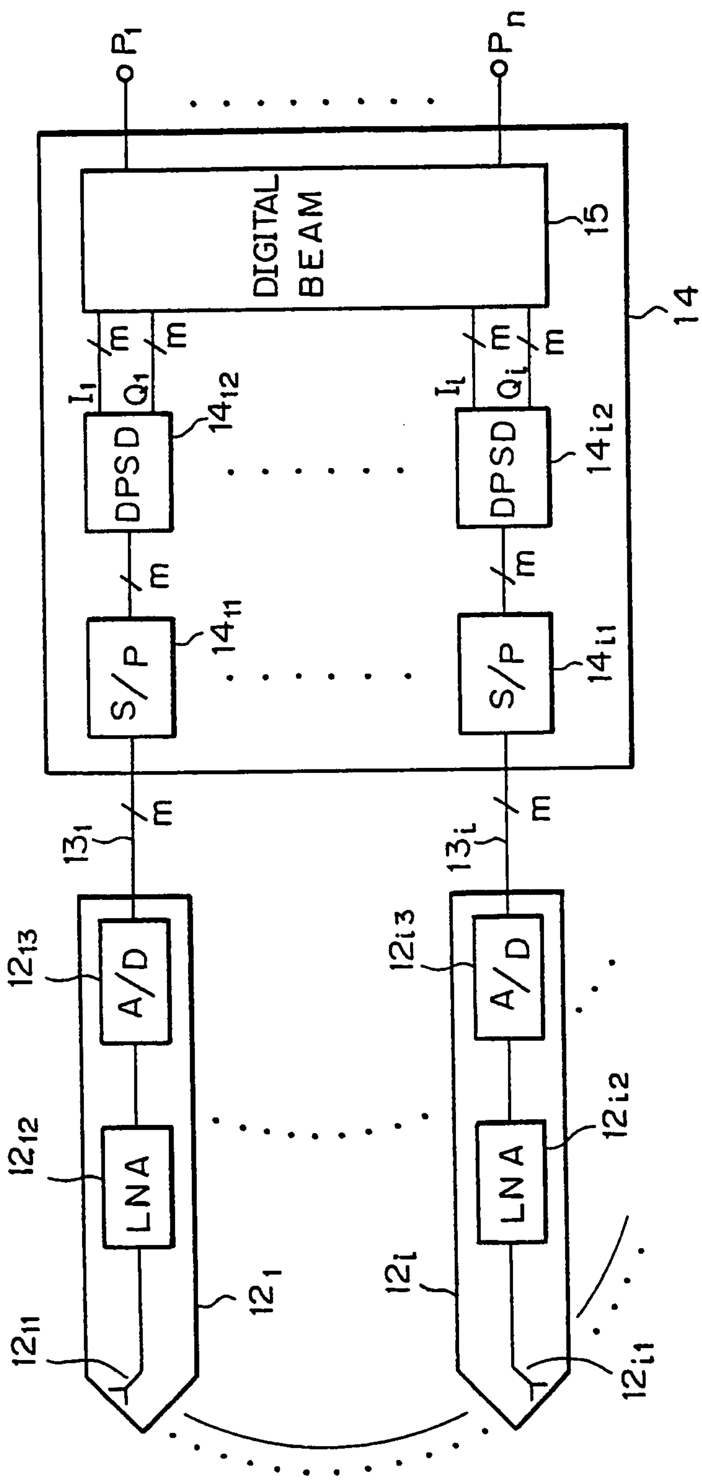

P1
Pn
DIGITAL BEAM
15
14
I1
Q1
Ii
Qi
m
DPSD
1412
14i2
S/P
1411
14i1
131
13i
A/D
1213
12i3
LNA
1212
12i2
121
12i
1211
12i1

Fig. 5

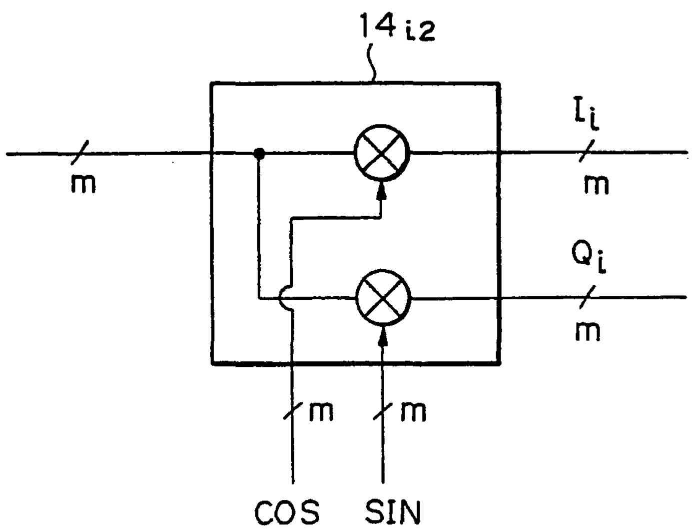

14_{i2}
I_i
m
m
Q_i
m
m
m
COS
SIN

Fig. 7

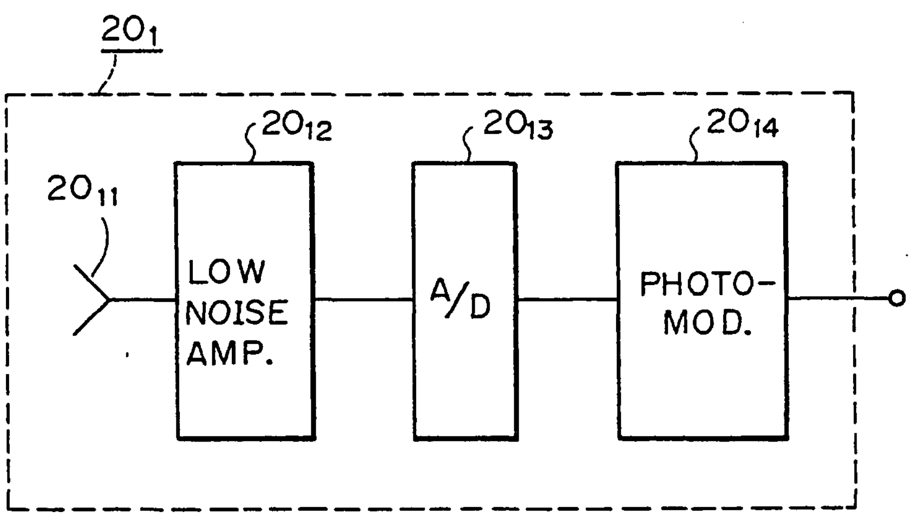

20_1
20_{12}
20_{13}
20_{14}
20_{11}
LOW
NOISE
AMP.
A/D
PHOTO-
MOD.

Fig. 6

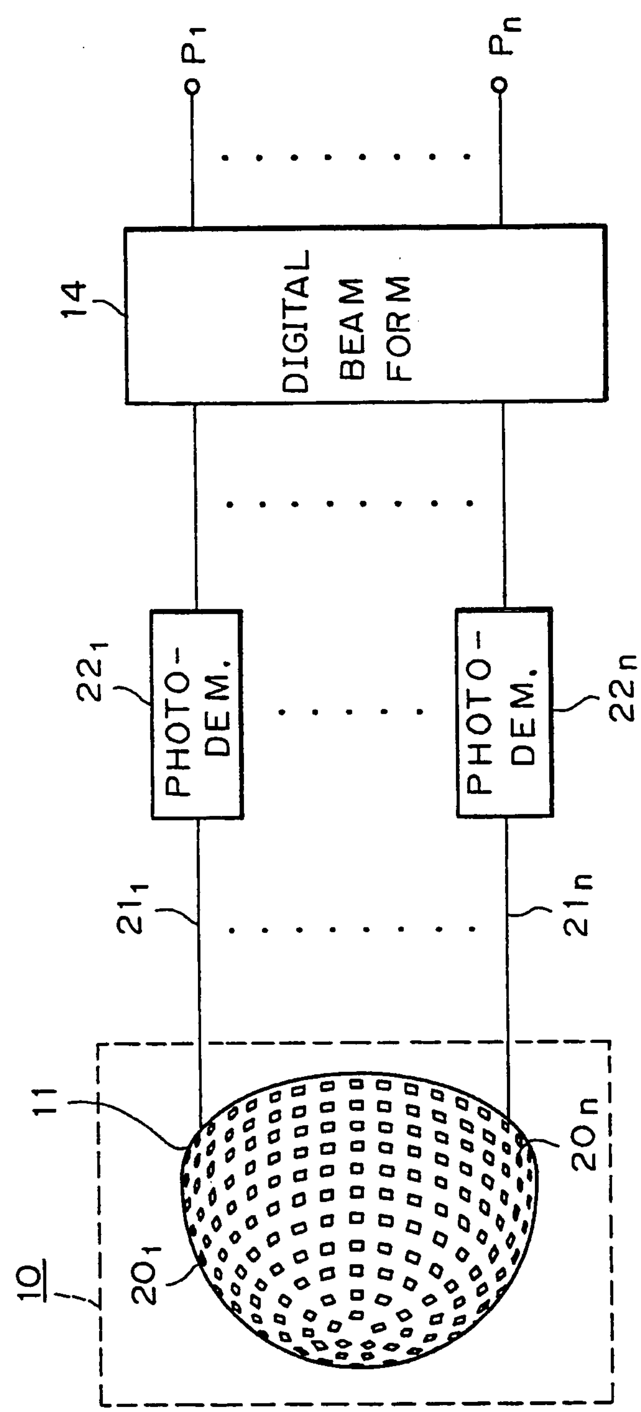
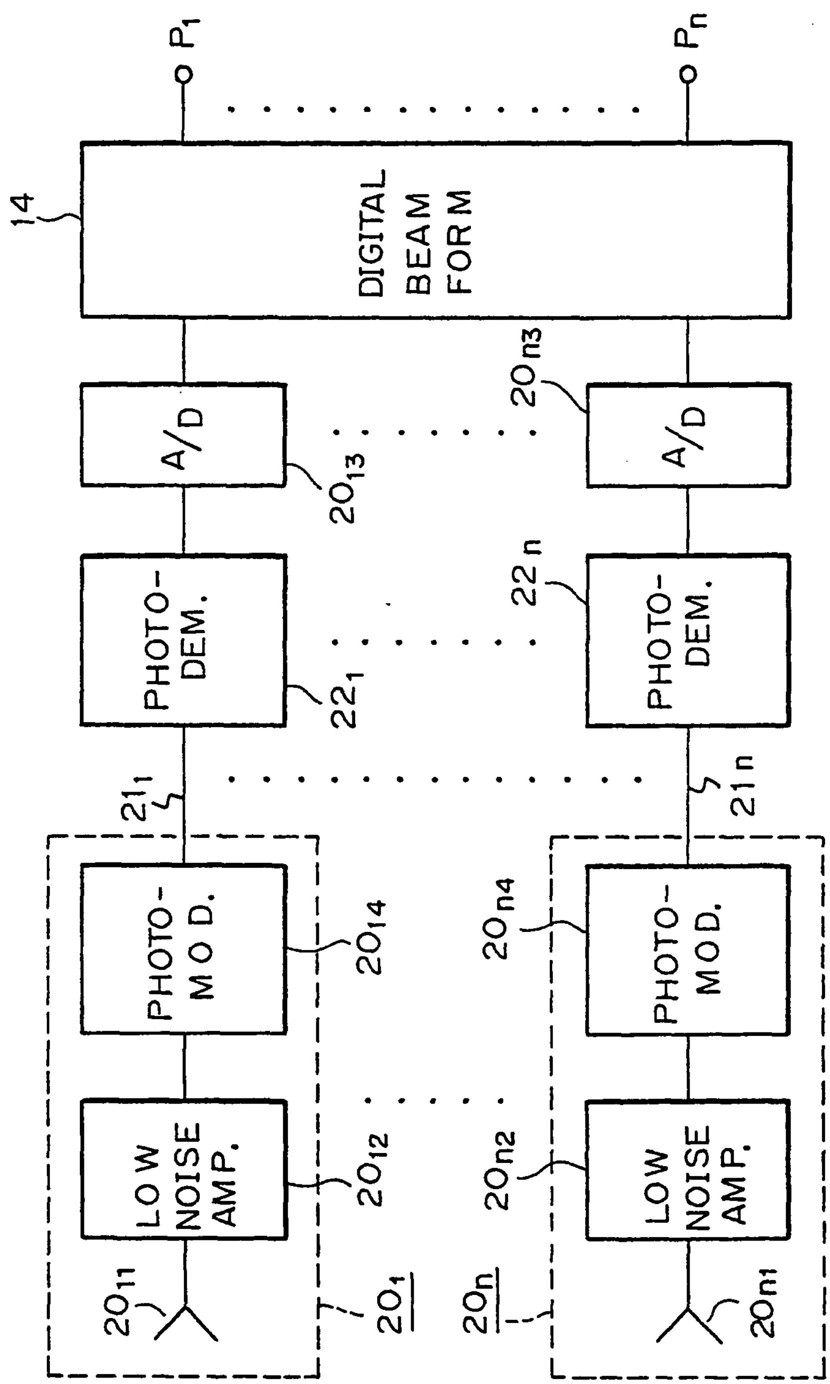

P1
Pn
14
DIGITAL
BEAM
FORM
221
PHOTO-
DEM.
PHOTO-
DEM.
22n
211
21n
11
20n
201
10

Fig. 8


P1
Pn
14
DIGITAL BEAM FORM
A/D
A/D
20n3
2013
PHOTO-DEM.
PHOTO-DEM.
221
22n
211
21n
PHOTO-MOD.
PHOTO-MOD.
2014
20n4
LOW NOISE AMP.
LOW NOISE AMP.
2012
20n2
2011
20n1
201
20n

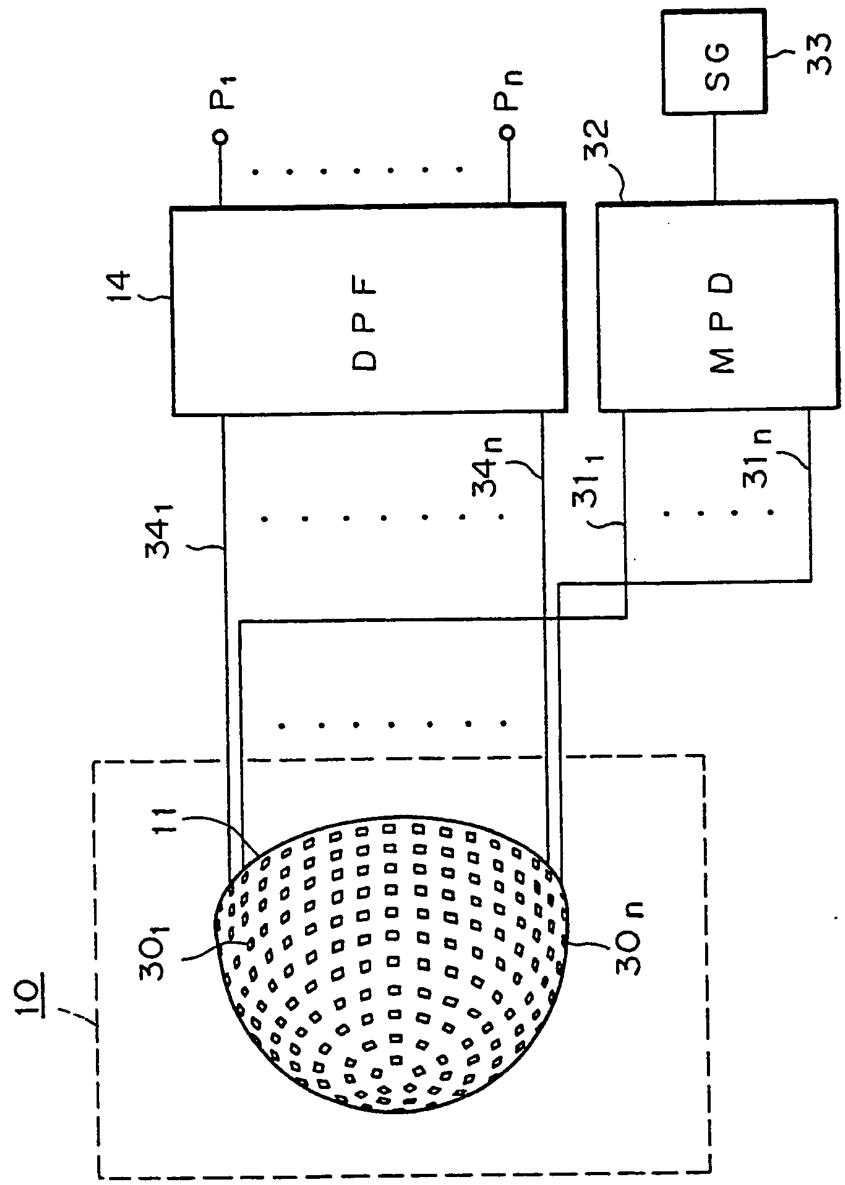


Fig. 9

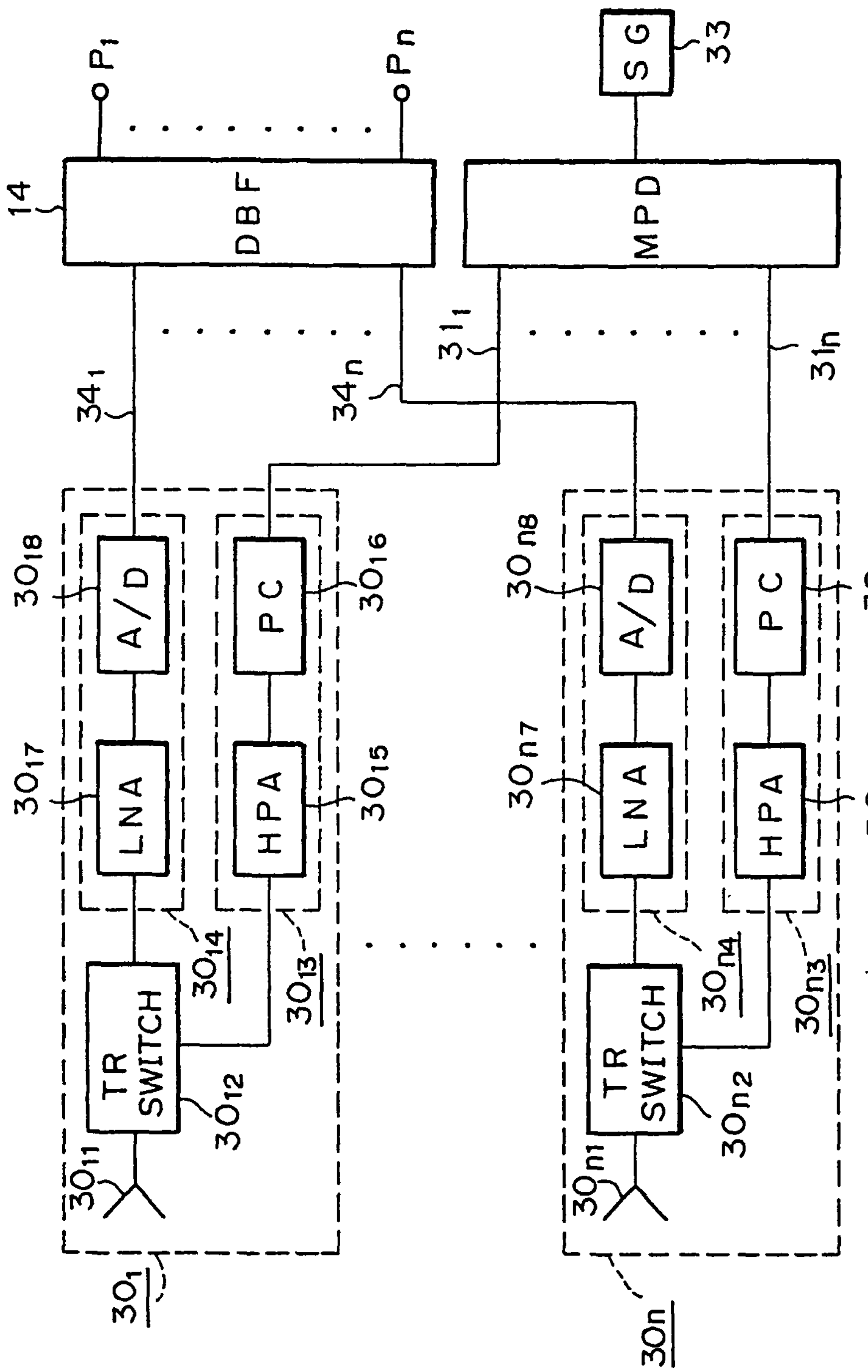

P1
Pn
SG
33
14
DBF
MPD
34_1
34_n
31_1
31_n
A/D
LNA
PC
HPA
TR SWITCH
30_{11}
30_{12}
30_{13}
30_{14}
30_{15}
30_{16}
30_{17}
30_{18}
30_1
30_{n1}
30_{n2}
30_{n3}
30_{n4}
30_{n5}
30_{n6}
30_{n7}
30_{n8}
30_n

Fig. 10

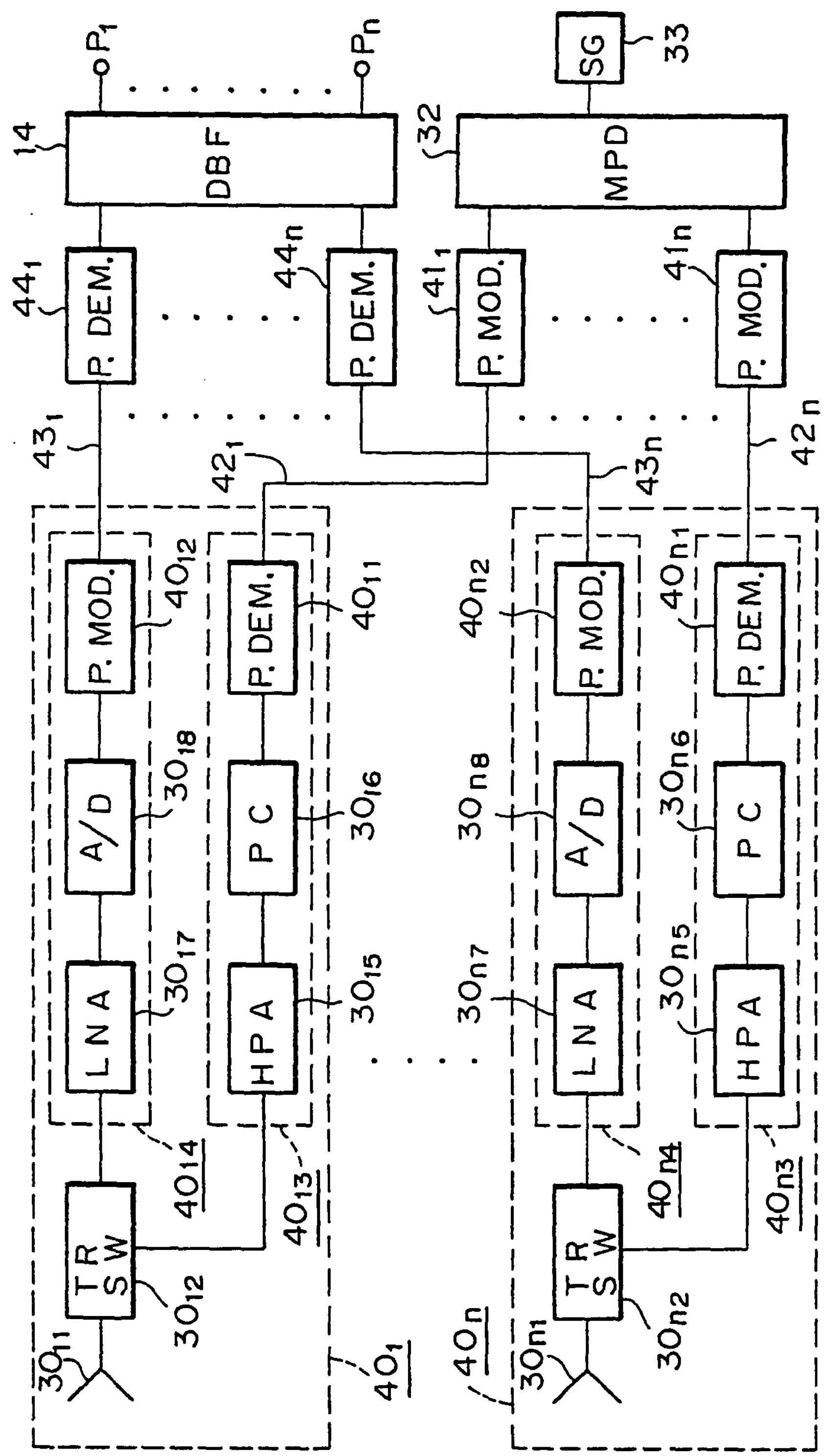
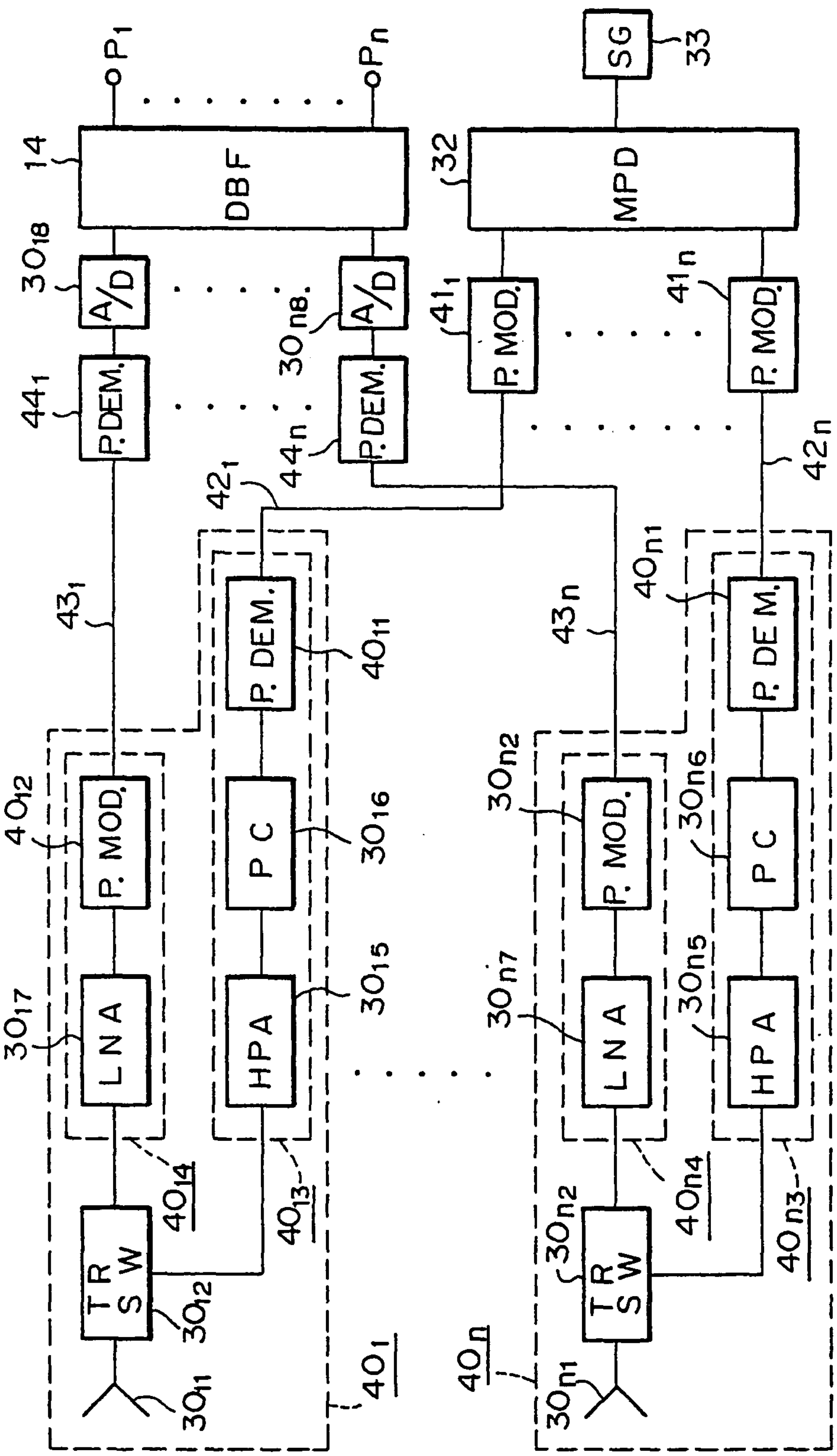

P1
Pn
SG
33
14
DBF
32
MPD
44₁
P. DEM.
44n
P. DEM.
41₁
P. MOD.
41n
P. MOD.
43₁
42₁
43n
42n
P. MOD.
40₁₂
P. DEM.
40₁₁
A/D
30₁₈
P C
30₁₆
L N A
30₁₇
H P A
30₁₅
T R S W
30₁₂
30₁₁
40₁₄
40₁₃
40₁
40n
P. MOD.
40n2
P. DEM.
40n1
A/D
30n8
P C
30n6
L N A
30n7
H P A
30n5
T R S W
30n2
30n1
40n4
40n3

Fig. 11

Fig. 12


DBF
MPD
SG
A/D
P. DEM.
P. MOD.
P. DEM.
P. MOD.
P C
LNA
HPA
TR SW
14
32
33
P_1
P_n
40_1
40_n